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Shifts in population dietary patterns and physical inactivity as determinants of global trends in the prevalence of diabetes: An ecological analysis

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Abstract *Background and aims:* The worldwide epidemiology of diabetes is rapidly changing as a result of the spreading of westernised nutritional and lifestyle habits. We conducted an ecological analysis to identify dietary, lifestyle and socio-economic factors associated with global diabetes prevalence.

Methods and results: Country-specific estimates of diabetes prevalence were obtained. Data were then matched to year- and country-specific food and energy availability for consumption, and to year-specific information on obesity, physical inactivity, urbanisation, gross domestic product (GDP), and smoking. Data were obtained from publicly available databases compiled by the Food Agricultural Organisation (FAO), World Health Organisation (WHO) and World Bank .Cluster analysis was used to derive dietary patterns of global food consumption. The association with diabetes prevalence was evaluated. Stepwise multiple regression analysis was conducted to identify predictors associated with worldwide diabetes prevalence.

96 countries were eligible for inclusion in the analysis. The average diabetes prevalence was 7.0% and the highest rate was observed in the Middle-Eastern region (13.1%). The worldwide prevalence of obesity and physical inactivity was 15.1% and 36.1%, respectively. Diabetes prevalence was associated with age and physical inactivity prevalence in a fully adjusted multiple regression model. Three dietary patterns (agricultural, transitional and westernised) were identified by the cluster analysis. Diabetes prevalence showed a direct dose–response association with the degree of exposure to a westernised dietary pattern.

Conclusions: The adoption of sedentary lifestyle and westernised dietary patterns appears to be closely linked to the global rise in diabetes prevalence.

Introduction

Diabetes is a metabolic disorder characterised by elevated blood glucose levels which considerably increase the risk for cardiovascular diseases (CVD) [1]. The global burden of diabetes is steadily rising and developing countries are experiencing steeper increments [2,3]. The association between diabetes and CVD mortality is linked to the damaging effects of hyperglycaemia as well as to the co-occurrence of other metabolic and vascular disorders such as hypertension, dyslipidaemia and atherosclerosis [4].

The nutrition transition model describes socio-economic, lifestyle and dietary drivers of the global trends in Non-Communicable Diseases (NCDs) [5]. Expansion of global trade, higher income and cheaper food enhance availability and affordability of food products,

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which may predispose to increased energy intake and the adoption of non-indigenous dietary patterns [6,7]. Typically, these dietary patterns have been characterised by an increased consumption of animal-based products, refined grains, sugar-sweetened beverages and vegetable oils [8,9].

Physical activity patterns are also rapidly changing, in association with urbanization. Levels of physical labour are declining, while sedentary behaviours are increasing [10]. Rapid advances in technology are rapidly changing behaviour across the globe [11] and these technological innovations occur alongside increased urbanisation rates which have a major impact on the assimilation of sedentary behaviours [7,11].

Diabetes is associated with a progressive impairment of the ability to efficiently metabolize glucose [12]. Diabetes has been linked with weight gain and obesity, but associations with other factors including age, physical inactivity and dietary factors (e.g., high glycaemic index, low fibre intake, sugar-sweetened beverages) have also been reported [6,8,13]. However, research on these risk factors has been conducted almost entirely in high income countries, and their association with diabetes risk in less affluent countries has been insufficiently investigated [14].

Our primary aim was to conduct an ecological analysis to identify dietary and lifestyle factors associated with between-country variability in the prevalence of diabetes using stepwise multiple regression analysis. We also performed a cluster analysis of worldwide data on food consumption to ascertain typical dietary patterns able to describe between-country variability in energy and food consumption, and evaluate their associations with the prevalence of obesity and diabetes.

Methods

The study was undertaken in three phases (Fig. S1, Online Supplementary Material). First, inclusion and exclusion criteria for selection of the prevalence estimates of diabetes were defined. Second, a search for the most recent information on prevalence rates reported for each country was conducted using the WHO GlobalInfoBase database (web link: https://apps.who.int/infobase/Indicators.aspx). Third, year- and country-specific Food Balance Sheets (FBS), urbanisation, physical inactivity and smoking rates, obesity prevalence, and *per capita* GDP estimates were retrieved. The project was undertaken between January and September 2013.

Prevalence of diabetes: The most recent diabetes prevalence rates were extracted for each country until 2010 (the latest year with available data on food consumption). If data for the same year originated from different surveys, the average of the reported values was calculated and included in the database. We included all diagnostic methods of diabetes such as self-reported, physician diagnosis, blood test. A summary of diagnostic methods used in each individual survey is provided in the Online Supplementary Material. Information on age range, sample size, survey identification code and the type of survey (national or sub-national) was also collated. Age was calculated as the midpoint of the age range of the survey. Prevalence estimates from national surveys were entered first and sub-national data was used if national estimates were unavailable. Prevalence estimates for obesity (BMI $\geq$30 kg/m^2) were also obtained using the same WHO database. Countries were included regardless of the diagnostic protocols (physical measurement, self-reported) used in each survey for the assessment of obesity status.

Food Availability for Consumption: The FAOSTAT database developed by the Food and Agriculture Organization was accessed to obtain data on food availability consumption for each country until 2010 (web link: http://faostat.fao.org/site/368/default.aspx#ancor). Food balance sheets (FBS) were used to extract information on energy availability for consumption from a selected list of commodities including: 1) Cereals, 2) Starchy roots, 3) Sugar cane, 4) Sugar beet, 5) Sugar, 6) Sweeteners, 7) Honey, 8) Sugar and sweeteners, 9) Pulses, 10) Vegetable oils, 11) Vegetables, 12) Fruits, 13) Alcoholic beverages, 14) Meat, 15) Animal fat, 16) Eggs, 17) Milk, 18) Fish, 19) Seafood. Sugar included energy available for consumption from sugar beets and sugar cane. Total sugar consumption (all sugar = sugar + sweeteners + honey) was used in the analyses. Total food import (tons/year) was also extracted for each country. A schematic representation of the classification of the food products used in the analysis is provided in the Online Supplementary Material (Fig. S2).

Smoking: Current smoking prevalence of any tobacco product (crude rate) for adult populations (individuals aged 15 years and above) was taken from the Global Health Observatory Data Repository (web link: http://apps.who.int/gho/data/#).

Physical Inactivity: The WHO Global Health Observatory Data Repository database (web link: http://apps.who.int/gho/data/node.main.A893?lang=en) was used to extract the level of physical inactivity for each country. Physical inactivity was defined as not meeting any of the following criteria; (1) at least 30 min of moderate–intensity activity per day on at least 5 days per week (2) at least 20 min of vigorous-intensity activity per day on at least 3 days per week or (3) an equivalent combination. Surveys were only included if they reported activity across all domains of life; for example, work, household, transport and leisure time [15].

Per Capita Gross Domestic Product (GDP): The World Bank database (web link: http://data.worldbank.org/indicator/NY.GDP.PCAP.CD) was utilised to obtain the year-specific *per capita* GDP (in U.S. dollars) for each country. *Per capita* GDP is gross domestic product divided by midyear population size. *Per capita* GDP was used to categorise countries in low (<$1000), lower middle ($1000–$3999), upper middle ($4000–$11999) and high income ($\geq$$12000) groups.

World Geographical Location: Countries were categorised in the following world regions: SSA = Sub-Saharan Africa, CA = Central Asia, EA = East Asia, EU = Europe, LA = Latin America, NA = North America, NAF = North Africa, AUA = Australasia and Pacific Islands.